What is the law of conservation of information?

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When they talk about the law of conservation of information, always describe the partial disappearance of information in a black hole, which is a violation of this law. But, for further analysis, we need to understand a little about the physical process under consideration. That is, let's analyze the physical essence of the transformations.

So, first, a little quantum mechanics. A quantum state is any possible state that a quantum system can be in. Most importantly, quantum states are of two different types (fundamentally different!):

1. “A pure state is a fully specified quantum state. If a given quantum object (for example, some elementary particle) is in a pure state, this means that we have all the information about it. Only pure states can be fully described by wave functions” [1].

2. “A mixed state (a mixture of states) is a state of a quantum-mechanical system, in which the maximum complete set of independent physical quantities that determine the state of the system is not specified... Thus, unlike a pure state, a mixed state is not described by a single wave function, but is described density matrix” [2]. That is, if an elementary particle is in a mixed state, then we do not have complete information about this particle.

And now we can describe the paradox of the disappearance of information in a black hole. If any body of a certain mass falls into a black hole, then it does not matter what kind of body it was, and in what internal state it was, the properties of the black hole after the absorption of the body will be determined only by its new mass. But, the black hole will lose mass due to the hypothetical Hawking radiation [3], so there will come a time when its mass will be equal to the original mass (before the body hits). That is, the black hole turned the original body into radiation, but did not change itself (since it returned to its original mass).

“In this situation, the following paradox becomes apparent. If we consider falling into a black hole and subsequent evaporation for a quantum system in some pure state, then - since the black hole has not changed as a result - we will get a transformation of the initial pure state into a “thermal” (mixed) state. Such a transformation is non-unitary, and all quantum mechanics is based on unitary transformations. Thus, this situation contradicts the original postulates of quantum mechanics” [4].

Simply put, our black hole has transformed the pure state of a quantum system (a falling quantum system) into a mixed state of a quantum system (a radiated quantum system) without changing itself. It turns out that the black hole destroyed some of the information, since we emitted a mixed state instead of a pure state. Therefore, a paradox arises.

But, in fact, there is no paradox. The thing is that we initially took an unproven fact as a postulate: that all black holes can be fully described only by three parameters: mass, electric charge and angular momentum. This is what the no hair hypothesis claims [5]. This hypothesis is sometimes called a theorem, but it is not strictly mathematically proven, therefore it is still a hypothesis.

If black holes are not fully described by mass, charge and angular momentum, then the paradox disappears, since there will be additional parameters of the black hole. And as we know, black holes consist of quark-gluon plasma, and to describe them, you need to know not only the mass of the black hole, but also the radius of its “drop” from the quark-gluon plasma, and the pressure of the quark-gluon plasma inside the black hole [6]:

“....in black holes, baryonic matter is converted into quark-gluon plasma. A black hole consists of a small core (“drop” from QGP) and a large gravitational radius. In small black holes, the radius of the core of the quark-gluon plasma will be equal to the gravitational radius. In large black holes, the radius of the QGP core will be much less than the gravitational radius. ...The minimum mass of a black hole, and its minimum radius, will vary over a wide range of values depending on the state of the QGP inside the black hole”.

Therefore, after the evaporation of the particle (radiation), the black hole will have the same mass, but still it will be different. Since a quark-gluon plasma is essentially a quark soup, which consists of quarks, antiquarks and gluons, and therefore, even with the same mass, due to quantum fluctuations, it will already be different [7]. Interestingly, if a black hole consists of a quark-gluon plasma, then a black hole resulting from the gravitational collapse of matter and a black hole of the same mass resulting from the gravitational collapse of antimatter will be exactly the same, and from the point of view of an external observer, they really will not be differ.

1. Pure states. Quantum state. Wikipedia. Quantum state – Wikipedia.
2. Mixed states. Quantum state. Wikipedia. Quantum state – Wikipedia.
3. Hawking radiation. Wikipedia. Hawking radiation – Wikipedia.

4. Black hole information paradox. Wikipedia. Black hole information paradox – Wikipedia.
5. No-hair theorem. Wikipedia. No-hair theorem – Wikipedia.
6. Bezverkhniy V. D. Bezverkhniy V. V. Black Holes and Quark-Gluon Plasma. SSRN Electronic Journal (2020). Abstract. DOI: 10.2139/ssrn.3675936. https://vixra.org/pdf/2008.0126v1.pdf
7. Quark–gluon plasma. Wikipedia. Quark–gluon plasma – Wikipedia.
8. Quora: What is the law of conservation of information? https://qr.ae/pNbznR